NORTHERN WILD SHEEP & GOAT SYMPOSIUM
★ WHITEFISH, MONTANA ★
2018

The 21st Biennial Symposium of the Northern Wild Sheep & Goat Council

May 21-24, 2018
Whitefish, Montana

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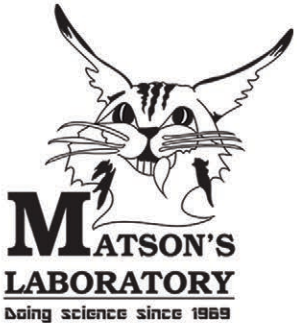

Robert Henderson

The 21st Biennial Symposium

of the

Northern Wild Sheep & Goat Council

May 21-24, 2018

Grouse Mountain Lodge

Whitefish, Montana

Northern Wild Sheep and Goat Council

Table of Contents

Notice to all attendees: As a courtesy to all presenters, we request that you turn off or silence your cellular phones while attending sessions and meetings.

Cover Photos Courtesy of Brent Lonner

General Symposium Information

Meeting Introduction

Welcome to the 21st biennial symposium of the Northern Wild Sheep and Goat Council (NWSGC). This symposium will take place 21-24 May, 2018 in Whitefish, Montana. As with previous symposia, this year's symposium offers an extensive selection of contributed oral and poster presentations, social activities and the annual Council business meeting. The symposium field trips are either a trip into Glacier National Park or to Wild Horse Island. Further information on the field trips is included in this program.

Introduction and Purpose of the NWSGC

The Northern Wild Sheep and Goat Council is a non-profit, international scientific and educational organization dedicated to the management and conservation of northern wild sheep and mountain goat populations and their habitats in North America. The Northern Wild Sheep Council was established in 1968 by a group of scientists from the U.S. and Canada. In 1978, the organization was renamed the Northern Wild Sheep and Goat Council, to reflect our interest in mountain sheep and mountain goats in North America.

The NWSGC purpose is achieved by:

1. Providing for timely exchange of research and management information.
2. Promoting high standards in research and management; and
3. Providing professional advice on issues involving wild sheep and mountain goat conservation and management.

Membership in the NWSGC includes professional research and management biologists and others active in the conservation of wild sheep and mountain goats. Membership in the Council is achieved either by registering at, or purchasing proceedings of, the biennial symposium. Only members may vote at the biennial business meeting.

Symposium Host City

Welcome to Whitefish, Montana. Though trappers, traders, loggers and waves of westward immigrants passed through the area during the second half of the 19th century, it wasn't until 1903 when the present location of Whitefish was officially established. The community was named for its location near Whitefish Lake. The Great Northern Railway was built through Whitefish beginning in 1904, which further sparked development of the town. The first passenger train arrived at the Whitefish Depot on October 4, 1904. The area was originally known as Stumptown due to the abundant amount of timber that had to be cleared to build the town and railroad and because tree stumps were left in the streets throughout downtown. Early residents of the town worked for the railroad and nearby logging industries. Timber, farming, ranching and the railroad were the backbone of the town's economy, and culture, for the next several decades. By the late 1940s, with the successful construction of a ski resort on Big Mountain (a collaboration among local businessmen), followed by a large golf course development, as well as it's close proximity to Glacier National Park, the tourism sector became increasingly important. Today, tourism is a leading industry to Whitefish's local economy.

Conference Venue

Since 1984, Grouse Mountain Lodge has welcomed guests to upscale comfort. The Lodge sits just over 1 mile from downtown Whitefish. The location of the Lodge is optimal for unique area recreational opportunities and is considered one of Montana's finest lodge facilities. The Grouse Mountain Lodge experience includes a full-service on-site restaurant, bar, swimming pool, day spa, coffee bar and more.

Registration and Logistics

Registration Fees:

Early Registration (Through April 15, 2018) – <u>Early Full registrants</u> will receive a Patagonia Fleece Vest with 2018 MT NWSGC Symposium embroidered logo.

Registrant Type	Activity	Price
General[1]	21st NWSGC Symposium	US$ 150.00
Student[1] [2]	21st NWSGC Symposium	US$ 75.00
Retiree[1] [3]	21st NWSGC Symposium	US$ 75.00
1-day only[4]	21st NWSGC Symposium	US$ 80.00
Field Trip[5]	Field Trip 1 or 2	US$ 50.00

[1] Includes Monday night reception, all conference presentation sessions, Tues, Wed & Thurs breakfasts and lunches, field trip transportation (for those attending) and Wed. Evening dinner.

[2] Students are considered an individual that is currently enrolled at an academic institution.

[3] Retirees are considered an individual that has retired from a working or professional career.

[4] Includes all scheduled activities/meals for that day (Tues or Thurs). Wed. Field trip cost is separate.

[5] Field trip includes transportation and lunch for the day.

Late Registration (After April 15, 2018)

Registrant Type	Activity	Price
General[1]	21st NWSGC Symposium	US$ 200.00
Student[1] [2]	21st NWSGC Symposium	US$ 100.00
Retiree[1] [3]	21st NWSGC Symposium	US$ 100.00
1-day only[4]	21st NWSGC Symposium	US$ 100.00
Field Trip[5]	Field Trip 1 or 2	US$ 50.00

[1] Includes Monday night reception, all conference presentation sessions, Tues, Wed & Thurs breakfasts and lunches, field trip transportation (for those attending) and Wed. Evening dinner.

[2] Students are considered an individual that is currently enrolled at an academic institution.

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[4] Includes all scheduled activities/meals for that day (Tues or Thurs). Wed. Field trip cost is separate.

[5] Field trip includes transportation and lunch for the day.

Cancellation/Refund Policy

Registration fees will be refunded less a $25.00 processing fee if cancellation notice is received by May 4, 2018.

The Symposium registration desk will be open at the following times:

Monday, May 21, 1600 – 2000

Tuesday, May 22, 0700 – 1700

Thursday, May 24, 0700 – 1200

*Locate Caryn Dearing at the conference if you need to register outside the designated times.

Symposium Contact and Organizing Committee:

Bruce Sterling/Co-chair, MT Fish, Wildlife & Parks
Brent Lonner/Co-chair, MT Fish, Wildlife & Parks
Caryn Dearing/Financial and Accommodations, MT Fish, Wildlife & Parks
Kevin Hurley/Executive Director, Northern Wild Sheep & Goat Council

Other Symposium Logistical Support Provided By:

Field trips:

- Charter Bus Reservations, Tim Thier, MT Fish, Wildlife & Parks
- Wild Horse Island, Bruce Sterling, MT Fish, Wildlife & Parks
- Glacier National Park, Mark Biel, National Park Service

Sponsor Solicitation – Organizing Committee (see above)

Chair of Business Meeting – Kevin Hurley/Executive Director, Northern Wild Sheep & Goat Council

Guest Speaker Organization – Jim Williams, MT Fish, Wildlife & Parks

Presentation/Poster Abstracts – Kelly Proffitt, Sonja Andersen, Karen Loveless and Brent Lonner – MT Fish, Wildlife & Parks

Conference Proceedings Editor – Justin Gude, MT Fish, Wildlife & Parks

Moderators – Kelly Proffitt, MT Fish, Wildlife & Parks

Program Development – Martha Lonner, Media Works Video & Publishing

We would like to thank the session moderators and many other volunteers that helped with conference logistics along the way as well as helping with the registration desk and other logistics during the conference.

Thank you to all the sponsors for their generous contributions and support. Sponsors are recognized in this program along with posters displayed during the conference.

Presenter Information

Oral Presenters – Continental Divide Room

Please take note of your presentation date and time. Please note that all general session talks should be limited to 20 minutes total (including time for questions). It is extremely important that we maintain this schedule. For general session talks, a brief (5 minute) period post-presentation should be left so members of the audience can ask a few questions. Take the time to practice so your delivery fits into the scheduled interval. Check with your session chair well in advance of the start of your session to make sure that you know where the tools are that you need for your talk (e.g., remote control, laser pointer) and how to use them. This is also the time to check and see if your PowerPoint presentation (ideally saved in Microsoft Office PowerPoint Show [.pps or .ppsx] format) runs properly on the projector and projection computer. Presentations should be uploaded no later than the break preceding your talk. Your session chair or one of the conference organizers can help you upload your presentation.

Posters – Glacier Room/Foyer

The poster session will be held during the Social on Monday May 21st. Posters will also be available for review during the session breaks Tuesday (May 22nd) and Thursday (May 24th). Poster displays should be set up between 1600 and 1800 Monday, prior to the Welcome Social. Posters should be mounted to foam board and displayed on an easel. Materials (tape, foam board, easels) will be available to presenters by request. Authors should be at their posters and prepared to discuss their work from 1830 to 1930 on Monday evening. Although posters will be displayed throughout the day on Tuesday and Thursday. Authors will not be required to be present, although it is encouraged to provide pertinent author contact information.

Abbreviated Symposium Conference Daily Schedule

Monday - May 21

16:00–20:00 Registration, Exhibitor set-up, check-in

18:00–21:00 Welcoming Reception/Poster Session (refreshments and appetizers included)

Tuesday - May 22

7:00–8:00 Breakfast (included with registration) Registration/Check-in, Exhibitor setup-up

8:00–8:30 Welcome/Symposium Introduction

8:30–12:00 Guest Speaker and Morning Session (break included with Posters displayed)

12:00–13:00 Working Business Meeting Lunch (included with registration)

13:00–17:00 Afternoon Session (break included with Posters displayed)

Dinner on your own — Explore Whitefish

Wednesday - May 23

7:00–8:00 Breakfast (included with registration) Registration/Check-in

8:15–16:30 Field Trips – Option 1 or 2 (lunch included)

Those participating in either field trip need to be prepared for all weather conditions (clothing and boots/shoes). Depending on interest/availability, registered Symposium participants will be given priority with regard to attending the field trips.

Option 1: *Glacier National Park* (All day, travel by buses, light hiking):

Visit Glacier National Park to learn more about mountain goat and bighorn sheep habitat, population status, management issues and past/ongoing research efforts. Glacier National Park is a 1,583 mi^2 wilderness area in Montana's Rocky Mountains, with glacier-carved peaks and valleys running to the Canadian border. It's crossed by the mountainous Going-to-the-Sun Road. More than 700 miles of hiking trails provide access to its remote backcountry areas as well as opportunities to view its diversity of wildlife, including one of the largest populations of mountain goats in the lower 48 states. Pending snow conditions, the group will take a 4.5 mile round trip hike to Avalanche Lake (730 feet elevation gain) to obtain some perspective on local park habitat, management and research related to mountain goats and bighorn sheep.

Option 2: *Wild Horse Island* (All day, bus/boat ride, little walking):

Visit Wild Horse Island to learn more about the islands history, especially with respect to past and ongoing bighorn sheep management. At 2,160 acres, Wild Horse Island is the largest island in a freshwater lake west of Minnesota. Wild Horse Island has been a landmark since the Salish-Kootenai Indians were reported to have used it to pasture horses to keep them from being stolen by other tribes. The park is noted for its wildlife including bighorn sheep, mule deer, songbirds, waterfowl, bald eagles, and falcons, as well as five wild horses. Primary discussion on this trip will include Wild Horse Island history and more specifically, bighorn sheep management perspectives given its unique location. Due to boat travel logistics and normal Island visitor group size constraints, participants in this tour will be limited to not more than 40 individuals. If demand exceeds availability, individuals can partake in the Glacier National Park field trip.

18:00–21:00 Outside BBQ Dinner at Hotel (included with registration)

Abbreviated Symposium Conference Daily Schedule (cont.)

Thursday - May 24

7:00–8:00	Breakfast (included with registration) Registration/Check-in
8:00–12:00	Morning Session (break included with Posters displayed)
12:00–13:00	Lunch (included with registration)
13:00–16:00	Afternoon Session (break included with Posters displayed)

Douglas H. Chadwick, Guest Speaker

Mountain Goats and the Anthropocene

Douglas H. Chadwick is a wildlife biologist who studied mountain goat ecology and social behavior atop the Crown of the Continent for seven years. He has since worked as a natural history journalist, producing 14 popular books and hundreds of magazine articles on subjects from snow leopards to great whales to grizzly bears in the Gobi desert. Chadwick is a founding Board member of the Vital Ground Foundation, a conservation land trust, and serves on the Board of the Liz Claiborne Art Ortenberg Foundation, which supports wildlife research and community conservation programs throughout the world.

Photo by Karen Reeves

21ST BIENNIAL NORTHERN WILD SHEEP AND GOAT COUNCIL SYMPOSIUM SCHEDULE

- ***Poster presentations are organized alphabetically by lead author (last name) and title of poster.***
- ***Oral presentations are organized by author presenting (last name) and title (subject) of presentation.***
- ***All Oral presentations are located in the Continental Divide Room.***
- ***All Breakfasts, Lunches & Breaks are located in the Glacier Room/Foyer.***

TIME	MONDAY (MAY 21)
16:00 - 20:00	**REGISTRATION OPEN**
18:00 - 21:00	**WELCOME RECEPTION / POSTER SESSION (INCLUDED W/REGISTRATION) - GLACIER ROOM**

POSTERS
BLUM - NEXT GENERATION RUGGEDNESS INDICES FOR MODELING ESCAPE TERRAIN OF DESERT BIGHORN SHEEP AT LONE MOUNTAIN, NEVADA
BOWEN - INVESTIGATING DISEASE SUSCEPTIBILITY IN DESERT BIGHORN SHEEP
CHERRY - MOUNTAIN GOAT MONITORING IN YOHO, KOOTENAY, AND BANFF NATIONAL PARKS OF CANADA
COX - WILD SHEEP RAM HUNTING PERMIT PROCESS FOR WESTERN STATES AND PROVINCES
DIXON - DETERMINING POPULATION MANAGEMENT UNIT BOUNDARIES FOR MOUNTAIN GOATS IN SKEENA REGION
GAMMONS - CHALLENGES OF PREDATION MONITORING AND MANAGEMENT FOR SIERRA NEVADA BIGHORN SHEEP
GORDON - DEVELOPING A SPATIAL TOOL TO ENABLE MONITORING OF AIRCRAFT FLIGHTS AND COMPLIANCE WITH AVOIDANCE STRATEGIES FOR HELICOPTER SKIING OPERATIONS IN THE SKEENA REGION
JAHNER - THE GENETIC LEGACY OF 50 YEARS OF DESERT BIGHORN SHEEP TRANSLOCATIONS IN NEVADA
STEPHENSON - OBSERVATIONS AND RECOMMENDATIONS DURING CAPTURE OF BIGHORN SHEEP
TOSA - WHEN, WHERE, AND WHY DO CONTACTS OCCUR? INVESTIGATING INTERACTIONS BETWEEN BIGHORN SHEEP IN AND AROUND GLACIER NATIONAL PARK

TIME	TUESDAY (MAY 22)	
07:00 - 08:00	**BREAKFAST (INCLUDED W/REGISTRATION)**	
08:00 - 08:25	SYMPOSIUM INTRODUCTION/WELCOME	
08:25 - 08:55	GUEST SPEAKER - MR. DOUGLAS H. CHADWICK - MOUNTAIN GOATS AND THE ANTHROPOCENE	
	MORNING SESSION 1 - HARVEST & MANAGEMENT STRATEGIES	**MODERATOR - SONJA ANDERSEN**
09:00 - 09:20	GARWOOD - SELECTIVE REMOVAL MAY LEAD TO RECOVERY OF AILING BIGHORN SHEEP HERDS	
09:20 - 09:40	LOVELESS - AGE STRUCTURE OF HARVESTED MOUNTAIN GOATS AS A TOOL FOR ASSESSING SUSTAINABLE HARVEST	
09:40 - 10:00	SMITH - MONITORING OF HUNTED MOUNTAIN GOAT POPULATIONS IN WEST-CENTRAL ALBERTA: INSIGHTS GAINED OVER MORE THAN FOUR DECADES	
10:00 - 10:20	**BREAK (POSTERS AND EXHIBITORS)**	

	MORNING SESSION 2 - HABITAT USE, MANIPULATIONS, AND CHANGES	**MODERATOR - PETE MUENNICH**
10:20 - 10:40	NIETVELT - THE IMPACTS OF WILDFIRE ON MOUNTAIN GOAT WINTER RANGES IN SOUTHWESTERN BC	
10:40 - 11:00	SITTLER - FORAGE RESPONSE TO PRESCRIBED FIRE IN THE NORTHERN ROCKIES: IMPLICATIONS FOR STONE'S SHEEP AND ELK	
11:00 - 11:20	SHAKERI - SEASONAL AND SEX-SPECIFIC VARIATION IN SPACE USE AND SITE FIDELITY OF MOUNTAIN GOATS IN COASTAL ALASKA	
11:20 - 11:40	BIEL - HUMAN VISITATION LIMITS THE UTILITY OF PROTECTED AREAS AS ECOLOGICAL BASELINES	
11:40 - 12:00	LOWREY - CHARACTERIZING THE SEASONAL MOVEMENTS OF A NATIVE AND RESTORED BIGHORN SHEEP: A CASE FOR CONSERVING MIGRATORY PORTFOLIOS	
12:00 - 13:00	**BUSINESS LUNCH (INCLUDED W/REGISTRATION)**	
	AFTERNOON SESSION 1 - NUTRITION & HORN SIZE	**MODERATOR - TABITHA GRAVES**
13:10 - 13:30	GARROTT - AN EXPLORATION OF METABOLOMICS TO ASSESS PHYSIOLOGICAL STATES IN BIGHORN SHEEP	
13:30 - 13:50	WENDLING - ASSESSING DALL'S SHEEP HORN MORPHOMETRICS AS A MANAGEMENT TOOL	
13:50 - 14:10	LaSHARR - ROLE OF HARVEST AND ENVIRONMENTAL FACTORS ON HORN SIZE OF MOUNTAIN SHEEP	
14:10 - 14:30	MONTEITH - HORN SIZE AND NUTRITION IN MOUNTAIN SHEEP: CAN EWE HANDLE THE TRUTH?	
14:30 - 14:50	**BREAK (POSTERS AND EXHIBITORS)**	
	AFTERNOON SESSION 2 - GENETICS/GENOMICS	**MODERATOR - MIKE COX**
14:50 - 15:05	EPPS - AN OVERVIEW OF PAST AND PRESENT GENETIC STUDIES OF BIGHORN SHEEP: RECONCILING METHODS AND CONSIDERING APPLICATIONS FOR MANAGEMENT	
15:05 - 15:20	BUCHALSKI - GENETIC EVIDENCE OF LOCAL ADAPTATION IN DESERT BIGHORN SHEEP NATIVE TO THE GREAT BASIN	
15:20 - 15:35	CASSIRER - DOES POPULATION OF ORIGIN AFFECT TRANSLOCATION SUCCESS IN BIGHORN SHEEP	
15:35 - 15:50	FLESCH - EVALUATING SAMPLE SIZE TO ESTIMATE GENOMIC RELATEDNESS IN BIGHORN SHEEP POPULATIONS	
15:50 - 16:05	MIYASAKI - USING HISTORIC SPECIMENS TO PROVIDE INSIGHT INTO NATIVE BIGHORN SHEEP GENETIC DIVERSITY AND CONNECTIVITY IN IDAHO	
16:05 - 16:45	GENETICS/GENOMICS Q & A - GROUP DISCUSSION	
	DINNER ON YOUR OWN	

TIME	WEDNESDAY (MAY 23)
07:00 - 08:00	**BREAKFAST (INCLUDED W/REGISTRATION)**
08:15 - 16:30	**FIELD TRIP OPTION A OR B (LUNCH INCLUDED)**
18:00-21:00	**OUTDOOR BBQ DINNER (INCLUDED W/FULL REGISTRATION) - OUTSIDE PAVILION**

TIME	THURSDAY (MAY 24)
07:00 - 08:00	**BREAKFAST (INCLUDED W/REGISTRATION)**
08:00 - 08:10	HOUSEKEEPING
	MORNING SESSION 1 - POPULATION DYNAMICS **MODERATOR - JUSTIN GUDE**
08:10 - 08:30	LOHUIS - DALL'S SHEEP POPULATION DECLINES IN ALASKA'S CHUGACH RANGE MAY BE RELATED TO CLIMATE AND WEATHER PATTERNS
08:30 - 08:50	WHITE - PROJECTING THE EFFECTS OF CLIMATE CHANGE ON MOUNTAIN GOAT POPULATION DYNAMICS IN ALASKA
08:50 - 09:10	PANAGAKIS - THE INFLUENCE OF EARLY REPRODUCTIVE SUCCESS ON LONGEVITY AND LATE REPRODUCTIVE SUCCESS IN AN ALPINE UNGULATE
09:10 - 09:30	WIEDMANN - ECOTYPIC VARIATION IN POPULATION DYNAMICS OF REINTRODUCED BIGHORN SHEEP
09:30 - 09:50	DECESARE - CONTRASTING THE STATUS AND TRENDS OF NATIVE VS. INTRODUCED MOUNTAIN GOAT POPULATIONS IN MONTANA
09:50 - 10:20	**BREAK (POSTERS AND EXHIBITORS)**
	MORNING SESSION 2 - HABITAT USE & RELATIONSHIPS **MODERATOR - ROBERT GARROTT**
10:20 - 10:40	GRAVES - HABITAT SELECTION, MOVEMENT, DISEASE, AND POPULATION STRUCTURE OF A RE-INTRODUCED BIGHORN SHEEP POPULATION IN A CANYON ENVIRONMENT
10:40 - 11:00	LULA - IS HABITAT CONSTRAINING BIGHORN SHEEP (*Ovis Canadensis*) DISTRIBUTION AND RESTORATION? A CASE STUDY IN THE GREATER YELLOWSTONE ECOSYSTEM
11:00 - 11:20	CUNNINGHAM - EVALUATING SUCCESS FOR AN INTRA-MOUNTAIN RANGE TRANSPLANT OF BIGHORN SHEEP IN SOUTHWESTERN MONTANA
11:20 - 11:40	CARPENTER - SEASONAL USE PATTERNS AND MOVEMENTS OF MOUNTAIN GOATS IN THE MOUNT EVANS WILDERNESS, COLORADO
11:40 - 12:00	LOWREY - NICHE SIMILARITIES AMONG INTRODUCED AND NATIVE MOUNTAIN UNGULATES
12:00 - 13:00	**LUNCH (INCLUDED W/REGISTRATION)**
	AFTERNOON SESSION 1 - DISEASE 1 **MODERATOR - JULIE CUNNINGHAM**
13:10 - 13:30	CASSIRER - PNEUMONIA IN BIGHORN SHEEP: A RECENT REVIEW
13:30 - 13:50	WEYAND - FATAL PNEUMONIA IN BIGHORN SHEEP LAMBS: THE CRITICAL ROLE OF *Mycoplasma ovipneumoniae* CARRIER EWES
13:50 - 14:10	PATERSON - THE IMPLICATIONS OF IMPERFECT DETECTION FOR ESTABLISHING THE PRESENCE/ABSENCE OF PATHOGENS: A WEB-BASED RESOURCE FOR MANAGERS
14:10 - 14:30	BUTLER - DETECTION ERROR AND DEMOGRAPHIC VARIABILITY AMID PERVASIVE PNEUMONIA PATHOGENS IN BIGHORN SHEEP
14:30 - 14:50	**BREAK (POSTERS AND EXHIBITORS)**
	AFTERNOON SESSION 2 - DISEASE 2 **MODERATOR - CLAY BREWER**
14:50 - 15:10	SHRINGI - USE OF RAPID FIELD-BASED PCR TESTING TO DETECT *Mycoplasma ovipneumoniae* INFECTION IN BIGHORN SHEEP
15:10 - 15:30	BESSER - USE OF INTRA-NASAL ANTIBIOTICS AS AN AID TO CLEARING *Mycoplasma ovipneumoniae* CARRIAGE BY DOMESTIC SHEEP
15:30 - 15:50	HARRIS - A PILOT PROGRAM TO CREATE A SOURCE OF DOMESTIC SHEEP FREE OF *M. ovipneumoniae* FOR COOPERATING PRIVATE OWNERS
15:50 - 16:10	DENRYTER - VARIATION IN THE ANNUAL COST OF LIVING OF AN ENDANGERED POPULATION OF BIGHORN SHEEP

ORAL PRESENTATION ABSTRACTS

- *Abstracts are organized alphabetically by author presenting (last name).*

Use of Intra-nasal Antibiotics as an Aid to Clearing *Mycoplasma ovipneumoniae* Carriage by Domestic Sheep

THOMAS E. BESSER, *Washington State University Department of Veterinary Microbiology and Pathology, PO Box 647040, Pullman, WA, USA 99164*

DAVID CASEBOLT, *University of Idaho College of Agricultural and Life Sciences Sheep Center, 875 Perimeter Drive MS2331, Moscow, ID, USA 82844*

NICHOLAS HILL, *University of Idaho College of Agricultural and Life Sciences Sheep Center, 875 Perimeter Drive MS2331, Moscow, ID, USA 82844*

ABSTRACT: *Mycoplasma ovipneumoniae* is the primary cause of epizootic pneumonia of bighorn sheep (*Ovis canadensis*). Contacts with reservoir hosts of *M. ovipneumoniae*, domestic sheep and goats, may result in transmission of this bacterium initiating outbreaks of this disease. Efforts to control the disease have emphasized physical separation of bighorn sheep from these reservoir hosts; however, separation is challenged by the natural movements of bighorn sheep, by straying reservoir hosts, and by the apparent mutual attraction of these sheep species. The effectiveness of separation would be complemented by elimination of *M. ovipneumoniae* from reservoir host operations near bighorn sheep ranges. Elimination of *M. ovipneumoniae* may be achieved by removal of adult chronic carriers and by segregated weaning of replacement stock, but these practices are limited by lack of facilities for effective on-farm segregation, by infection of replacements prior to weaning age, or by carrier prevalences exceeding the operator's tolerance for culling. Clearing *M. ovipneumoniae* with antimicrobial drug therapy would circumvent these limitations. Here we report that combined systemic and local therapy can eliminate this pathogen from domestic sheep.

Pilot studies of systemic (subcutaneous) treatment of chronic carrier ewes with enrofloxacin, gamithromycin, tildipirosin, and tulathromycin failed to eliminate *M. ovipneumoniae* nasal carriage. However, combined systemic and intranasal enrofloxacin treatment successfully cleared *M. ovipneumoniae* from two carrier domestic ewes for >3 months. Two subsequent enrofloxacin trials examined yearling lamb (n=28) and adult ewe (n=15) carriers randomly assigned to one of 4 treatment groups in 2x2 factorial designs. Factors were 1) systemic treatment (yes or no) and 2) intranasal wash dosage (low or high). In both trials, animals treated with systemic enrofloxacin combined with either high or low dose intranasal treatment became PCR negative for *M. ovipneumoniae*. Carrier animals that failed to clear *M. ovipneumoniae* following intranasal-only therapy did clear the infection when subsequently treated with combined therapy. These results indicate that combined antimicrobial therapy can eliminate M. ovipneumoniae carriage by domestic sheep. Further studies are needed to 1) document the durability of *M. ovipneumoniae clearance*, 2) determine the efficacy of combined therapy in domestic goats, and 3) optimize antimicrobial drug choices and dosing levels.

Human Visitation Limits the Utility of Protected Areas as Ecological Baselines

MARK J. BIEL, *National Park Service, Glacier National Park, West Glacier, MT, USA 59936*

WESLEY SARMENTO, *Montana Fish, Wildlife and Parks, Conrad, MT, USA 59425*

JOEL BERGER, *Wildlife Conservation Society, Bronx, NY 10460/Department of FWC Biology, Colorado State University, Fort Collins, CO, USA 80523*

ABSTRACT: A key goal of protected areas is the conservation of biodiversity. Increasing visitation, however, can compromise ecological integrity. A fundamental conundrum is that if parks are to serve as our most pristine places, then we must understand how human presence alters biological interactions. Species that redistribute themselves closer to people is of growing management concern both in and out of national parks because of 1) human safety, 2) animal health, and 3) ecological consequences. Drivers of distributional change are often dissimilar but may include increased association with people for predator avoidance – the human shield hypothesis. We examine redistribution patterns with comparative, observational, and experimental approaches contrasting ecological responses of an iconic species in a USA national park - Glacier. Specifically, we focused on the role of predator avoidance and resource enhancement to test whether a cold-adapted alpine obligate, mountain goats, (*Oreamnos americanus*), mediate their distribution by increasing spatial overlap with humans. Individuals that enhanced mineral acquisition through access to human urine concomitantly reduced behavioral and ecological responses to grizzly bear (*Ursus arctos horribilis*) experiments. Goats near people also displayed reduced group sizes, vigilance, use of escape terrain, and forfeited migrations to naturally occurring minerals. Our findings re-enforce the increasing complexities of natural area management because visitation is altering ecological interactions. While protected areas offer some forms of baselines for scientists and enjoyment for millions of visitors, redistribution of species and associated ecological changes signifies that additional care will be needed in what we perceive as pristine and what is anthropogenically-altered.

Genetic Evidence of Local Adaptation in Desert Bighorn Sheep Native to the Great Basin

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CLINTON EPPS, *Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR USA 97331*

WALTER BOYCE, *Wildlife Health Center, University of California, Davis, CA, USA 95616*

MARJORIE MATOCQ, *Department of Natural Resources and Environmental Science, University of Nevada, Reno, NV, USA 89557*

RACHEL CROWHURST, *Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR, USA 97331*

BRANDON HOLTON, *Science and Resource Management, Grand Canyon National Park, AZ, USA 86023*

LAURA THOMPSON, *National Climate Change and Wildlife Science Center, U.S. Geological Survey, Reston, VA, USA 20192*

ESTHER RUBIN, *Wildlife Research Branch, Arizona Game and Fish Department, Phoenix, AZ, USA 85086*

JAMES CAIN, *New Mexico Cooperative Fish and Wildlife Research Unit, U.S. Geological Survey, Las Cruces, NM, USA 88003*

ABSTRACT: Desert bighorn sheep (*Ovis canadensis nelsoni*) occupy a diversity of desert ecosystems throughout the southwestern United States. Significant climatic differences among these desert ecosystems suggests the potential for adaptation to local conditions in this taxon. We tested for signatures of local adaption using 2b-RAD reduced representation genotyping in conjunction with high resolution

climate data for 30 native populations of desert bighorn sheep (291 individuals) distributed throughout much of its North American range. Population differentiation and ecological association tests on 11,303 SNPs identified outlier loci with alleles private to the Great Basin of California and Nevada. Private allele frequencies were correlated with higher elevation and lower annual mean temperature; logistic regression, $P < 0.001$. Outlier loci mapped to a ~ 5 Mb sequence on chromosome 8 of the domestic sheep genome (Oar v3.0) encompassing the EPH receptor A7 gene and six other undescribed protein coding genes. Our data suggest the few remaining desert bighorn herds native to the Great Basin may represent a unique ecotype and should be managed accordingly. Understanding the range of adaptive genetic variation present within desert bighorn sheep may prove instrumental in predicting how this taxon might respond to global climate change.

Detection Error and Demographic Variability Amid Pervasive Pneumonia Pathogens in Bighorn Sheep

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ABSTRACT: Respiratory disease (pneumonia) has been a persistent challenge for bighorn sheep (*Ovis canadensis*) conservation and its cause has been attributed to numerous bacteria including *Mycoplasma ovipneumoniae* and several *Pasteurellaceae* family species. This study sought to investigate efficacy of diagnostic protocols in detecting *Pasteurellaceae* and *Mycoplasma ovipneumoniae*, generate sampling recommendations for different protocols, assess the distribution of these disease agents among 21 bighorn sheep populations in Montana and Wyoming, and evaluate what associations existed between detection of these agents and demographic performance of bighorn sheep populations. Analysis of

replicate samples from individual bighorn sheep revealed that detection probability for regularly used diagnostic protocols was generally low (<50%) for *Pasteurellaceae* and was high (>70%) for *Mycoplasma ovipneumoniae*, suggesting that routine pathogen sampling likely mischaracterizes respiratory pathogen communities. Power analyses found that most pathogen species could be detected with 80% confidence at the population-level by conducting regularly used protocols multiple times per animal. Each pathogen species was detected in over half of the study populations, but after accounting for detection probability there was low confidence in negative test results for populations where *Pasteurellaceae* species were not detected. Eighty percent of study populations hosted both *Mycoplasma ovipneumoniae* and leukotoxigenic *Pasteurellaceae* pathogens, yet a number of these populations were estimated to have recruitment rates greater than 30% and positive population growth. The results of this work suggest that disease severity is influenced by ecological factors and/or differences in pathogen communities that cannot be assessed using methods currently available to most wildlife managers. These results also suggest that continued respiratory disease epizootics may be caused by pathogens already resident in bighorn sheep populations as well as by the introduction of novel pathogens. We present a framework to evaluate these hypotheses and develop management strategies aiming to minimize the effects of respiratory disease in bighorn sheep amid pervasive respiratory pathogens.

Seasonal Use Patterns and Movement of Mountain Goats in the Mount Evans Wilderness, Colorado

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ABSTRACT: Mountain goats (*Oreamnos americanus*) were introduced into the Mount Evans area in 1961. From 1961 until the mid-1970s the mountain goat population stayed mainly below tree line and were occasionally observed in the alpine. By the mid-1980s, use shifted to the alpine near Lincoln Lake year round. Based on summer ground surveys, established in 1978, the population used more of the available alpine habitat than was observed in the mid-1980s and mountain goat numbers have fluctuated over time from a low of 44 (1978) to a high of 167 (2001) (minimum count). In 2013, there was an unknown disease outbreak affecting kids and yearlings resulting in loss of almost an entire age class in this herd. Satellite collars were placed on mountain goats (n=20) between 2015 and 2016 to determine if habitat use had changed since the 1980s, evaluate the overall and seasonal habitat use, and monitor condition of kids associated with collared females for potential reoccurrence of the 2013 disease outbreak. Results suggest habitat use by mountain goats has changed dramatically since the 1980s. Mountain goats used more available alpine habitat compared to the 1980s, but no collared animals were observed in the Lincoln Lake area. Collared animals used 18.4% (16.13 km^2) of the overall available habitat (87.3 km^2). Seasonal habitat use is markedly different between summer and winter use. Based on MaxEnt (for maximum entropy) modeling, elevation had the highest relative importance to the summer model (>0.60); whereas for winter it was the terrain ruggedness index (>0.80).

Does Population of Origin Affect Translocation Success in Bighorn Sheep?

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ABSTRACT: Since 1922, over 21,000 wild sheep have been translocated within and among states and provinces in western North America for species restoration (Western Association of Fish and Wildlife Agencies Wild Sheep Working Group). In Idaho, bighorn sheep have been translocated since the 1960's

from multiple states and provinces including Oregon, Wyoming, Montana, Alberta, British Columbia, and within Idaho. Several sources are often used to reestablish a single population to increase numbers and genetic diversity. As a result, despite small founder sizes, many of Idaho's reintroduced populations have similar or greater allelic richness than native populations. However, it is unknown whether translocated individuals from different source populations contribute equally to numbers and genetic diversity. We used 10 neutral microsatellite markers to empirically evaluate the genetic composition of restored populations in Idaho, and their sources. We then simulated the expected present-day genetic composition of the re-established populations, under the assumption that translocated individuals from each source population performed equally. By comparing the empirical genetic data with the simulation results, we evaluated whether the assumption of equal fitness across translocation sources was violated, and therefore whether certain source populations were more successful than others. This analysis could help inform decisions to increase the success of future translocations.

Pneumonia in Bighorn Sheep: A Recent Review

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ABSTRACT: In this presentation, we review the literature and recent unpublished data to present a brief overview of the biology and management of pneumonia in bighorn sheep. Association of domestic sheep has long been linked to pneumonia outbreaks in free-ranging bighorn sheep and has been confirmed in 13 captive commingling experiments. Epizootic pneumonia in bighorn sheep is polymicrobial but

Mycoplasma ovipneumoniae, a bacterium specific to *Caprinae* and commonly carried by healthy domestic sheep and goats, appears to be a necessary primary agent. All-age epizootics following introduction of *M. ovipneumoniae* along with other pathogens into bighorn sheep populations are usually severe (median mortality 48%) but fatality rates vary widely, from 5 – 100%. Disease outcomes may be influenced by the strain of *M. ovipneumoniae*, by co-infection with other bacterial and viral pathogens, and by factors associated with transmission and host immunity. Once introduced, *M. ovipneumoniae* can persist in bighorn sheep populations for decades. Carrier dams transmit the pathogen to their susceptible lambs, triggering fatal pneumonia outbreaks in nursery groups, which limit recruitment and slow or prevent population recovery. The result is that demographic costs of pathogen persistence often outweigh the impacts of the initial introduction. Strain typing suggests that spillover of *M. ovipneumoniae* into bighorn sheep populations from domestic small ruminants is ongoing, and that consequences of spillover are amplified by movements of infected bighorn sheep across populations. Current disease management strategies focus on reducing risk of spillover from reservoir populations of domestic sheep and goats and on limiting transmission among bighorn sheep. A broad array of approaches has been tried and more are needed to prevent pathogen introduction, induce disease fadeout in persistently infected populations, and promote population resilience across the diverse landscapes bighorn sheep inhabit.

Evaluating Success for an Intramountain Range Transplant of Bighorn Sheep in Southwestern Montana

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ABSTRACT: Montana Fish, Wildlife and Parks (MFWP) performed three bighorn sheep transplants within the Madison Mountains of southwest Montana to repopulate a historic, but unoccupied, winter range. The existing (source) herd had endured and recovered from several all-age die-offs, and numbered approximately 200 animals prior to the start of transplants. An unoccupied winter range approximately 14 miles north was chosen as the release site due to a combination of biological and social factors. MFWP and Montana State University captured bighorn sheep using a drop net, and moved 52, 22, and 23 bighorn sheep in wintertime 2015, 2016, and 2018 (total = 97 bighorn sheep). The drop net enabled selection of social and family groups for transplant. We transplanted 16 lambs, 57 ewes, 23 rams, and 1 unclassified sheep. Older rams (>3.5) were avoided in transplant to prevent them from injuring lambs or smaller sheep in the trailer during transport. A sample of released bighorn ewes were fitted with LOTEK Lifecycle GPS collars at each transplant (10 in 2015, 6 in 2016, and 11 in 2018), which provided location data daily for up to 3 years. Mortalities included 4 predations, 2 injuries, and 1 unknown cause of death. Mortalities can be compared to non-transplanted, collared study animals from the source herd (8 mortalities across 32 VHF and GPS collars on ewes 2012-2018). Transplant success, defined by the percentage of bighorn sheep which remained in the transplant area after 1 year (i.e., did not return to the capture site) varied from

approximately 20% in 2015 to approximately 80% in 2016, with 2018 still underway. Released bighorn sheep did not necessarily stay together in groups and individual movements varied across an area of approximately 625 km^2. Results suggest managers can use intramountain range captures and transplants to achieve success in expanding occupiable winter ranges and establishing a desirable metapopulation structure. Intramountain transplants have advantages of using local animals familiar to the ecological landscape and local predator suite, and with common movement behaviors (i.e., migratory or non-migratory strategies) and pathogen communities. Managers may have to capture and release for several years to see success.

Contrasting the Status and Trends of Native vs. Introduced Mountain Goat Populations in Montana

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ABSTRACT: Among jurisdictions inhabited by mountain goats (*Oreamnos americanus*), Montana has a unique history of management to sustain large populations of both native and introduced animals. More than 75 years ago, the state wildlife agency began transplanting mountain goats (495 animals to 27 locations) into previously unoccupied mountain ranges. We synthesized harvest and population data from 1960–2015 for all native and introduced populations across the state. Supplementing these data with responses to a questionnaire sent to the 18 Montana Fish, Wildlife and Parks' biologists that manage goats, we assessed past trends and current status of Montana's mountain goats. As introduced populations have generally prospered—numbering 2,525 or 69% of the statewide population—native populations (outside Glacier National Park) have declined from an estimated 4,100 during the 1940s to about 1,160 (31%) of the statewide population in 2016. We show that many populations are small and potentially demographically isolated, which poses challenges both for conservation and for collecting rigorous monitoring data. Whereas native herds sustained 80–90% of public harvest 50 years ago, introduced populations have produced 85% of the statewide harvest in recent years. Our survey of biologists identified likely causes of population changes and a wide range of management and research needs that would benefit mountain goat management.

Variation in the Annual Cost of Living of an Endangered Population of Bighorn Sheep

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ABSTRACT: Energy is fundamental to survival, growth, and reproduction with effects that scale up to influence larger-scale processes including movements, habitat selection, and population productivity. Coarse estimates of the amount of energy wild animals need to make a living rarely have been quantified or related to larger-scale processes. Our objective was to develop a tool to calculate energy budgets of bighorn sheep based on body mass, reproductive status, and movement data. We used empirical data from Sierra Nevada bighorn sheep (*Ovis canadensis sierrae*) that were captured during 2001–2016 and fitted with GPS collars, weighed, and assessed for reproductive status. Resting metabolic rates (reported

in the literature) were the foundation of energy budgets; we added costs for eating, walking, and sinking in snow. Empirical data for reproduction and replenishment of body fat for bighorn sheep were not available in the literature, so we estimated these costs based on data for related species while correcting for allometric scaling relationships. Annual energy requirements varied with sex, reproductive status, and migratory tactic. Our model provides the basis for quantifying energetic implications of migration tactic for sheep and estimates of energy intake needed for optimal reproductive output. Coupling our model with estimates of food supplies may provide insights into energetic motivations of habitat selection and aid in establishing estimates of nutritional carrying capacity. Our energy model can be adapted to any population of free-ranging sheep if annual body mass (and fat) dynamics, reproductive status, and movement rates are known.

An Overview of Past and Present Genetic Studies of Bighorn Sheep: Reconciling Methods and Considering Applications for Management

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ABSTRACT: Bighorn sheep have been the focus of genetic research for decades. Because of small populations sizes, natural and anthropogenic habitat fragmentation, and a long history of bottlenecks and founder effects from translocation, managing low genetic diversity has been a concern across much of the present-day range of bighorn sheep. We review past, present, and possible future directions for studies of bighorn sheep that incorporate genetic tools or address genetic management. We consider two broad and not necessarily exclusive categories of studies or approaches: those intended to use genetic signals to infer phylogeography and phylogenetic relationships, demographic history, patterns of fragmentation and connectivity, or population size, and those intended to examine the consequences of genetic variation within populations, such as inbreeding, effects of genetic diversity on fitness, local adaptation, response to disease, and heritability of desirable traits. We provide a brief overview of different methods and questions, describe examples from past and present research, consider which types of methods and markers are most appropriate for different situations, and discuss how these concepts have been applied to management of wild sheep populations in North America. Finally, we identify areas of uncertainty and questions that bear examination in future research.

Evaluating Sample Size to Estimate Genomic Relatedness in Bighorn Sheep Populations

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ABSTRACT: Genetic research may be a useful approach for understanding factors that could impact productivity and restoration of bighorn sheep herds. For example, genetic consequences of inbreeding in small populations can impact recruitment, and relative relatedness among herds can help inform translocation decisions. This empirical simulation study quantified genetic attributes of bighorn sheep

populations with a range of different herd histories in Montana and Wyoming to investigate genomic relatedness within and between herds and to estimate an optimal sample size per population for evaluating genetic diversity and distance. Employing an Ovine array containing ~700,000 single nucleotide polymorphisms (SNPs) with approximately 24,000 markers that are informative for Rocky Mountain bighorn sheep, we conducted whole genome genotyping. We analyzed genetic material from 30 individuals from each of four different populations that we predicted would differ in genetic characteristics due to population dissimilarities that included origin (native/reintroduced), population size, bottleneck history, degree of connectivity, and augmentation history. The four populations provided samples across a spectrum of these herd attributes and included Fergus, Taylor-Hilgard, and Glacier National Park in Montana and the Beartooth Absaroka in Wyoming. We examine relatedness estimates within herds using two different metrics to evaluate the potential for links between genomics and herd demography. By evaluating our simulation results, we conclude that a sample size of 25 is adequate for assessing intra- and inter-population relatedness. We discuss the utility of genetic analyses for improving knowledge of bighorn sheep populations and potential implications for bighorn sheep management.

An Exploration of Metabolomics to Assess Physiological States in Bighorn Sheep

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ABSTRACT: Wildlife biologists have limited and relatively crude tools for assessing the health, physiology, and nutritional condition of bighorn sheep and other wild ungulates yet physiological attributes of an animal play a fundamental role in susceptibility to disease, reproduction, probability of survival, and can provide insights into the relative quality of landscapes occupied. Nuclear Magnetic Resonance spectroscopy (NMR) is an emerging technology that can identify and quantify a large suite of biological molecules (metabolites) in a blood serum sample that are products of a wide range of physiological processes. NMR-based metabolomics is being aggressively developed in the fields of human medicine and agriculture animal production in the pursuit of discovery of disease biomarkers and to detect metabolic shifts in a myriad of physiological pathways that can be bioindicators of nutritional and other environmental stresses. To explore the potential of this technology for wildlife management we collected 949 serum samples from 14 wild bighorn sheep herds in Montana and Wyoming, as well as samples from two captive research herds. These samples represented animals suspected of experiencing a range of physiological conditions including gradients in dietary intake, degree and duration of starvation, and transitions from a healthy to a disease (pneumonia) state. Sample processing and assay techniques were refined and we successfully developed a library of 81 metabolites that can be accurately identified and quantified. We report on our analyses of these metabolic profile data to develop a 'health panel' to assess physiological states in bighorn sheep to inform restoration and management.

Selective Removal May Lead to Recovery of Ailing Bighorn Sheep Herds

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ABSTRACT: Bighorn sheep (*Ovis canadensis*), a culturally and economically valuable game species in the west, are suffering from a respiratory disease that has decimated infected populations. Biologists recently theorized that this disease is induced by the bacterium *Mycoplasma ovipneumoniae* (*Mo*) and have hypothesized that the propagation of *Mo* outbreaks stems from a small number of adult bighorns that chronically shed the pathogen. This induces periodic epizootics in the herd, resulting in adult mortalities, poor lamb survival, and ultimately population decline. We test this hypothesis by radio-marking and testing presence of *Mo* in two infected herds of bighorn sheep in the Black Hills, South Dakota, where disease histories had been developed for individual bighorns. In our experimental herd we radio-marked and tested all individuals in the population (n = 21 adults, n = 9 lambs) and removed chronic shedders based on disease histories; subsequent testing indicates Mo no longer persists in this herd. Our control herd (n = 46 adults, n = 19 lambs) still exhibits the presence of Mo and experienced 26% lamb mortality and 13% adult mortality due to pneumonia. The experimental population experienced no mortalities attributable to pneumonia. Adult survival for our control ($\hat{S}$ = 0.68, SE = 0.01) did not significantly differ (Z = 1.13, P = 0.19) from our treatment ($\hat{S}$ = 0.83, SE = 0.02) but may be biologically relevant. Lamb survival for our control ($\hat{S}$ = 0.16, SE = 0.02) was significantly lower (Z = 4.73, P < 0.01) than our treatment ($\hat{S}$ = 0.87, SE = 0.04), which suggests that the selective removal of Mo-shedding bighorns reduces pneumonia incidence and mortality in wild populations. This study has implications for wildlife managers across the west, as testing and removing chronic shedders may be more tenable than eradicating entire populations.

Habitat Selection, Movement, Disease, and Population Structure of a Re-Introduced Bighorn Sheep Population in a Canyon Environment

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ABSTRACT: We comprehensively assessed multiple management concerns for a re-introduced sheep herd in Dinosaur National Monument, Colorado, USA. We captured 20 bighorn sheep in late 2006, collected genetic and disease samples and deployed GPS collars that recorded locations every 2.5 hours for 18 months. We evaluated habitat selection and movement at 2 spatial scales. Bighorns selected home ranges near the river, where canopy cover was low, and for grasslands, shrublands, and woodlands versus non-vegetated areas. Within the home range, in summer, assessed with an integrated step selection function, bighorns selected for areas near escape terrain, low solar radiation, more westerly slopes,

moderate variation in local topography, and the canyon bottom or the rim, thus selecting against moderate elevations. Selection patterns in winter were similar, with additional selection for areas near permanent water and away from intermittent water. In terms of movement, bighorns strongly avoided crossing rivers, and selected areas with lower forest cover that were further from escape terrain. We detected movement across the rivers in one region, near the juncture of the Green and Yampa Rivers and found no genetic signal of population structure. Combined, these analyses suggest that the rivers and rugged canyons do not impede either demographic or genetic connectivity of bighorn sheep in the Monument and that they should be treated as a single herd. Results from the ELISA test suggest widespread exposure to *M. ovi*. These methods will help analysts working in other canyon systems and these findings will help local management of this re-introduced population.

A Pilot Program to Create a Source of Domestic Sheep Free of *M. ovipneumoniae* for Cooperating Private Owners

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ABSTRACT: Small ruminant owners indicate interest in lowering risk of pathogen transmission to bighorns while continuing to maintain their flocks. One promising approach is for owners to hold only animals free of *M. ovipneumoniae,* but managers lack sources for animals certified free of this pathogen to which they could refer partnering flock-owners. Because development of a *M. ovipneumoniae*-free flock was an experimental and untested process likely to entail up-front costs, the Washington Department of Fish and Wildlife (WDFW) decided to pave the way rather than expecting a private firm to shoulder these risks. We further reasoned that if we were successful, our experience would be useful to private breeders interested in expanding the program. An avenue for cooperation had previously been established by Washington's Sustainability in Prisons Project, which has raised endangered turtles and butterflies in state correctional facilities, providing valuable life-lessons for participating inmates. In early 2016, WDFW collaborated with the Washington Department of Corrections (DOC) to raise and breed for sale domestic sheep that could be certified free of *M. ovipneumoniae* at the Washington State Penitentiary in Walla Walla. WDFW contracted with 2 sheep experts to lead day-to-day operations, paid for testing and purchase of founder individuals, and, together with DOC, funded necessary infrastructure improvements. Fifteen Suffolk ewes, originating from 2 nearby herds, arrived onsite in late September 2017, and a ram was added in mid-October. In addition to testing PCR-negative twice for *M. ovipneumoniae*, as well as once for ovine progressive pneumonia virus, paratuberculosis and Caseous lymphadenitis (CL), all founder individuals were genotyped either RR or QR (for scrapie), vaccinated against Campylobacter and CL, and inspected by a veterinarian. Despite our precautions, the ram tested PCR-positive for *M. ovipneumoniae* approximately 5 weeks after arrival, and a week later, a ewe was also positive. Rapid isolation of infected individuals, coupled with 5-day antibiotic treatment with via nasal wash and subcutaneous injection was evidently successful in both preventing further spread and clearing the infected animals. All 16 animals were PCR-negative on 5 successive tests. Lambing will occur in March-April 2018, and we expect to have yearlings ready to provide to participating breeders in 2019.

Role of Harvest and Environmental Factors on Horn Size of Mountain Sheep

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ABSTRACT: Harvest-induced evolution can have important implications for the sustainable management of populations world-wide; yet, the true effects of harvest remain highly debated. Even at limited temporal and spatial scales, population-level responses to harvest can occur across taxa, and include reduced size of weapons and growth rate, and early sexual maturation. Nevertheless, in most populations, the threshold of selection intensity that prompts evolutionary change is unclear. Harvest can affect patterns of weapon size in two distinct ways. First, intensive harvest can result in demographic changes, where declines in mean weapon size result from an increasing proportion of young animals harvested through time. Alternatively, selection for males with fast-growing weaponry may favor the persistence of males with slow-growing weaponry through time and result in declines in the average size of weapons in a population despite no change in age structure. Mountain sheep (*Ovis canadensis* and *Ovis dalli*) represent an ideal system to test the effects of harvest on weapon size because harvest of mountain sheep is highly regulated throughout their range and a wealth of phenotypic data exists. Additionally, reliable age data, which is critical to test shifts in age structure of populations, is available through horn annuli of mountain sheep. We synthesized harvest records of mountain sheep throughout their range and assessed changes to age structure and horn size over 46 years. After accounting for age, temporal trends in horn size were not explained by changes to the age structure in approximately 20% of hunt areas, but instead may be associated with selective pressures or environmental conditions. Nonetheless, age-specific horn size was stable in about 80% of hunt areas, indicating harvest practices for most populations of mountain sheep in North America have not resulted in evolutionary changes to weapon size.

Dall's Sheep Population Declines in Alaska's Chugach Range May be Related to Climate and Weather Patterns

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ABSTRACT: Dall's sheep populations in the Chugach range in Alaska have declined 30-50% since the late 1980s. Research in two study areas was initiated in 2009 and 2012 to identify rates and causes of mortality, assess nutritional condition, screen for disease, and check pregnancy rates on adult (age 3-17) ewes. Additional objectives were to quantify rates and causes of mortality on lambs from natality to one year of age. In the absence of baseline data, the project was designed to identify primary factors influencing sheep populations in Southcentral Alaska. With 134 and 183 sheep-years of data on adult sheep in the two study populations, annual adult survival was 87% in each population. Lamb survival was 57% and 32%, respectively. While these rates are very similar to that reported in other study populations, pregnancy rates in Chugach ewes are low and variable, ranging from 18-88% in one population, and 44-96% in the other. It appears likely that weather, climate, nutrition, and habitat play a far greater role in shaping the trajectories of these populations than does predation. Using a combination of nutritional condition measures, forage quality assessment, and remote sensing, current research efforts are focused on assessing changes in habitat quantity and quality due to changing weather and climatic conditions. We will discuss data that led to the current research direction, and present preliminary results that suggest that tree and shrubline advance has reduced available habitat, and that warmer, drier weather has reduced diet quality. Together, these pieces of evidence suggest that carrying capacity has declined to support sheep populations at present levels.

Age Structure of Harvested Mountain Goats as a Tool for Assessing Sustainable Harvest

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ABSTRACT: Mountain goat (*Oreamnos americanus*) populations can be challenging to manage because of difficulties in effectively monitoring population trends and assessing demographic structure of populations. Population trends can be quite variable including irruptive dynamics in some introduced mountain goat populations and declining trends in many native populations, resulting in wide variation in sustainable harvest rates among populations. Impacts of harvest can be difficult to detect in a timely manner, resulting in negative consequences for the population. In South-central Montana there are several introduced mountain goat herds that have been managed by incrementally increasing harvest rates over time to manage population growth. The resulting harvest rates are comparatively high for mountain goat populations and have resulted in a dataset of over 3,000 harvested goats over the past 30 years. This study compared age at harvest based on incisor cementum analysis and horn annuli across populations with varying harvest rates and population trends. Horn morphology, sex ratio of harvested goats and hunter success rates were also compared with an objective of determining how useful these metrics are for identifying trends and assessing sustainability of harvest management. Results are discussed in the context of adaptive harvest management and implications for mountain goat management and conservation.

Niche Similarities Among Introduced and Native Mountain Ungulates

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ABSTRACT: When two ecologically similar species are sympatric, theory predicts they will occupy distinct ecological niches to reduce competition. We evaluated the niche partitioning hypothesis with sympatric mountain ungulates – native bighorn sheep (BHS; *Ovis canadensis*) and introduced mountain goats (MTG; *Oreamnos americanus*) in the northeast Greater Yellowstone Area. We characterized seasonal niches using two-stage resource selection functions with a used-available design and descriptive summaries of the niche attributes associated with used GPS locations. We evaluated seasonal similarity in niche space according to confidence interval overlap of model coefficients and similarity in geographic space by comparing model predicted values with Schoener's D metric. Our sample contained 37,962 summer locations from 53 individuals (BHS = 31, MTG = 22), and 79,984 winter locations from 57 individuals (BHS = 35, MTG = 22). Slope was the most influential niche component for both species and seasons, and showed the strongest evidence of niche partitioning. Bighorn sheep occurred on steeper slopes than mountain goats in summer and mountain goats occurred on steeper slopes in winter. The pattern of differential selection among species was less prevalent for the remaining covariates, indicating strong similarity in niche space. Model predictions in geographic space showed broad seasonal similarity (summer D = 0.88, winter D = 0.87), as did niche characterizations from used GPS locations. Our results suggest that reducing densities of mountain goats in hunted areas where they are sympatric with bighorn sheep and impeding their expansion may reduce the possibility of competition and disease transfer.

Characterizing the Seasonal Movements of a Native and Restored Bighorn Sheep: A Case for Conserving Migratory Portfolios

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ABSTRACT: Animal migrations represent the culmination of a long evolutionary history resulting in genetic, physiological, behavioral, and life-history traits that facilitate the successful interaction between individuals and biotic and abiotic factors in their environment. Once lost, attempts to restore migration generally result in diminished seasonal movements compared to historic migratory patterns. Over their broad distribution, bighorn sheep show diverse seasonal movements from resident to long-distant migrants spanning varied elevational and geographic gradients, yet much of our current understating of bighorn sheep movements stems from periodic tracking of animals instrumented with VHF collars sampled from single populations. While restoration efforts (i.e. translocations) have undoubtedly resulted in modest successes, bighorn sheep occupy only a small fraction of their former range and predominantly occur in restored populations that number fewer than 100 individuals. Although factors related to disease, competition, and habitat quality routinely inform bighorn sheep translocations, less attention has been given to seasonal movements, yet the tendency to migrate has been positively associated with translocation success. As an initial step to exploring the importance of migrations in bighorn sheep restoration, we used GPS location data to characterize the seasonal movements of over 200 female bighorn sheep across four states. Specifically, we evaluated the presence and diversity of migratory movements between restored and native herds. We report findings from this large-scale comparative analysis spanning herds with varied demographic performance and management histories, and propose stronger consideration of seasonal movements as an important component of future bighorn sheep restoration.

Is Habitat Constraining Bighorn Sheep (*Ovis canadensis*) Distribution and Restoration? A Case Study in the Greater Yellowstone Ecosystem

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ABSTRACT: Rocky Mountain Bighorn Sheep (*Ovis canadensis*) are believed to have historically existed within geographically distinct areas (e.g., mountain ranges) as naturally structured metapopulations, and efforts focused on restoring metapopulations may provide currently unrealized restoration opportunities. By rebuilding metapopulations, managers may not only increase bighorn sheep abundance and distribution, but may also promote natural recolonization, improve genetic heterozygosity and improve population resiliency to stochastic disease events. The Madison Mountain Range, located on the western edge of the Greater Yellowstone Ecosystem (GYE), is a good example of a mountain complex with apparent unrealized potential for restoration. We hypothesized that the range is capable of supporting a metapopulation of bighorn sheep, and that current distributions are not primarily limited by habitat availability. We instrumented 27 adult female bighorn sheep in the Taylor-Hilgard population, located on the southern end of the Madison Range, with GPS radio collars programmed to record spatial data for approximately 18 months. Based on these data, we generated resource selection function (RSF) models

to describe the seasonal movement of this population and evaluated their ability to predict current distributions of bighorn sheep within the Madison Range. Next, we extrapolated predictive models to identify areas of unoccupied habitat that could be considered for future translocation efforts aimed at establishing a continuous bighorn sheep metapopulation. Here, we discuss our models' performance, and utility for informing future bighorn sheep management within the Madison Range.

Using Historic Specimens to Provide Insight into Native Bighorn Sheep Genetic Diversity and Connectivity in Idaho

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ABSTRACT: Bighorn sheep *(Ovis canadensis*) have experienced severe population declines and population extirpations across the western US. One region where bighorn sheep were not extirpated is the Salmon River Drainage of Idaho. These native populations are a highly valuable and irreplaceable genetic and ecological resource. The goal of this study was to evaluate genetic diversity and connectivity among bighorn sheep in this region using a combination of current and historic specimens. Specifically, we addressed 4 questions 1) What are the levels of genetic diversity and population connectivity for native Idaho bighorn sheep? 2) Are Population Management Units (PMUs) genetically distinct? 3) What were historic levels of genetic diversity in native Idaho bighorn sheep? 4) How has diversity changed over time? We obtained 350 current samples from 5 PMUs, 43 historic samples (1989) from the Middle Main Salmon (MMS) and 34 historic samples (1923-1985) from Lower Salmon (LS) and Middle Fork (MF) using horn shavings from the Carrey Collection. We genotyped 15 microsatellite loci, eleven neutral and four adaptive. We observed the highest levels of genetic diversity in the historic samples from the Carrey Collection and from current samples in the core of the range. The Carrey Collection samples also had a much larger number of unique alleles (13) compared to the historic specimens from MMS (0) and current samples (3). Our connectivity and gene flow analyses indicated that PMUs were genetically distinct, but there was evidence for gene flow between PMUs. We found evidence for higher historic connectivity between the LS and MF PMUs compared to current samples from these regions. This is the first study in bighorn sheep to evaluate changes in genetic diversity over time using historic specimens and demonstrates that unique alleles and genetic diversity have been lost over time which has implications for fitness and adaptive capacity.

Horn Size and Nutrition in Mountain Sheep: Can Ewe Handle the Truth?

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ABSTRACT: Horns, antlers, and other horn-like structures are products of sexual selection, confer reproductive advantages, and are heritable and honest indicators of individual quality. In addition, horns and antlers also garner substantial societal interest that, when combined with the powerful motivation to acquire trophy animals, likely has spawned a growing "hornographic" culture fixated on males with exceptional horn-like structures. Intensive harvest of large, fast-growing males, however, may have deleterious effects on the very trait being sought, which has led to considerable controversy in the popular and scientific literature. Mountain sheep, possibly the only large ungulate in North America managed almost exclusively as a trophy species, embody this controversy because of the emphasis on managing for large males. That controversy has led to polarizing views among scientists and stakeholders as to how mountain sheep should be managed. Our goal herein was to discuss the relative contributions of the key ecological and intrinsic factors that influence horn growth, how those factors might interact with harvest strategies, and identify what determinants of horn size are most amenable to management and most effective in achieving desired outcomes. Given the hyperbole surrounding trophy management and big horns, we suggest the importance of females in the management of bighorn sheep has been largely forgotten. Females play a critically important role, not just as the reproductive segment of the population responsible for producing young, but because maternal condition can produce life-long effects on size and growth of males (via maternal effects); and additionally, abundance of females, in turn, affects nutritional limitation within populations through density-dependent feedbacks. Ultimately, we call for greater recognition of the pervasive role of the ewe—and other female ungulates—in the production of trophy males and in contributions to population performance; and accordingly, that they be better integrated into harvest and management programs.

The Impacts of Fire on Mountain Goat Winter Ranges in Southwestern British Columbia

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ABSTRACT: Over half of the world's population of mountain goats (*Oreamnos americanus*) occur in British Columbia; BC has a global responsibility for the conservation of this species. Mountain goats are particularly vulnerable during the winter months, when deep snows restrict their movements and distribution, especially in wet coastal environments. While the effects of disturbance on mountain goats resulting from such activities as helicopter use have been studied, the impacts of large-scale landscape perturbations such as wildfires have not. During the summer of 2015, significant wildfires occurred in the southwestern British Columbia covering approximately 19,000 ha in total area. As a result of these wildfires, several legally protected mountain goat winter ranges were burned to varying degrees. There is a concern that these wildfires will significantly affect the suitability of these winter ranges and negatively affect the survival of the mountain goat populations that depend on these habitats during the winter

months. During March and February of 2016 and 2017, we conducted two helicopter surveys of these winter ranges to assess the impacts wildfires had on mountain goat relative abundance (goats per km) and their habitats. In general, mountain goat relative abundance was highest in winter ranges with the lowest percentage (0-25%) of the forest burned, while relative abundance was the lowest in winter ranges with the highest percentage (80-100%) of the forest burned. When examining the relationship between forest cover (ha) with each winter range and mountain goat use, there appears to be a decline in mountain goat relative abundance as forest patch size decreases. This study provides an opportunity to examine the relationship between large-scale habitat perturbations and the impacts on mountain goat populations despite data gaps related to mountain goat population trends. These wildfires provide a unique opportunity for biologists and resource managers to assess the impacts of natural disturbance on wildlife populations and habitat use.

The Influence of Early Reproductive Success on Longevity and Late Reproductive Success in an Alpine Ungulate

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ABSTRACT: The life-history theories of aging predict lifetime trade-offs between early reproductive allocation and late-life survival, reproduction, or both components of fitness. Recent studies in wild populations have found evidence for these early-late life trade-offs, but rarely across multiple traits while exploring the additional effects of variation in environmental conditions and individual quality. Benefiting from longitudinal data on adult female mountain goats (*Oreamnos americanus*), we investigated the influence of age at first reproduction (AFR) and early reproductive success (ERS) on longevity, late reproductive success, and senescence rates, while accounting for the influence of natal environmental conditions and individual quality. Contrary to predictions, we did not find evidence for early-late life trade-offs. Instead, an earlier AFR and a greater ERS had positive but weak direct effects on late reproductive success. Natal population density, however, was the strongest determinant of all life-history traits, having a direct negative effect on female longevity, late reproductive success, AFR, and ERS. Although natal density reduced the probability of annual reproduction and annual survival during adulthood, higher allocation to reproduction in early life and poorer natal conditions did not lead to accelerated rates of senescence during adulthood. The results of this investigation provide an integrated picture of early-late life trade-offs, underscoring the importance of accounting for environmental conditions due to their potentially strong implications for population dynamics.

The Implications of Imperfect Detection for Establishing the Presence/Absence of Pathogens: A Web-Based Resource for Managers

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ABSTRACT: A key factor for the informed management of populations of wild animals is the ability to accurately determine the presence or absence of pathogens. The infection status of groups has important implications for the translocations of individuals, herd-level accreditation of freedom from infection, as well as understanding the risks of pathogen transmission between wild and domestic animals. However, accurately assessing the presence of pathogens is complicated by imperfect detection, which results in uncertainty regarding pathogen presence even in the face of no positive test results. The accurate assessment of pathogen presence also requires evaluating the consequences of assuming binomial or hypergeometric sampling. Here, we develop a flexible, Bayesian-based framework for estimating the probability of pathogen presence and its uncertainty. We demonstrate our approach by evaluating the consequences of imperfect detection for a variety of respiratory pathogens in bighorn sheep (*Ovis canadensis*). We then generalize this framework by developing a web-based application to make this estimation methodology more widely available. Using test results, this application allows users to estimate the probability of pathogen presence, or prevalence in the event of positive tests, by controlling parameters related to sampling design and detection probabilities. Furthermore, it informs sampling design by allowing users to determine the sample size and number of replicate tests per individual that are required to achieve a specified confidence in the probability of pathogen presence. Overall, this work has produced a practical, readily-accessible, and easily-used tool that will allow managers to assess the probability of pathogen presence/absence in wild populations.

Seasonal and Sex-Specific Variation in Space Use and Site Fidelity of Mountain Goats in Coastal Alaska

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ABSTRACT: Understanding patterns of animal space use and site fidelity have important implications for conservation. For species that live in highly seasonal environments, such as mountain goats (*Oreamnos americanus*), space use patterns are likely to vary due to changing environmental conditions and sex-specific selection pressures. In this study, GPS location data (n = 123,481 locations) were collected from 64 radio-collared mountain goats (males, n = 36; females, n = 28) in a coastal mountain range complex near Haines, Alaska during 2010 – 2017. These data were analyzed a GIS framework using Program R (rhr package) to derive seasonal and sex-specific fixed kernel home range estimates, and to quantify the degree of seasonal home range overlap. Overall, we determined that during the kidding season females with kids (1414±300 ha, n = 24) had smaller homes ranges than females without kids (2278±599, n = 22). Presumably this occurred due to the limited physical mobility of neonates and heightened vulnerability to predation. We also determined that females (2636±307 ha, n = 57) had larger home ranges than males (1424±155 ha, n = 74) during the summer, and males had larger home ranges (2400±155 ha, n= 67) than females (848±307 ha, n = 45) during the rut; home ranges during winter were similar in size for males (464±89 ha, n = 66) and females (543±100, n = 57) but substantially smaller than other times of year. Expansion of female home ranges during summer may be related to high energetic acquisition needs of reproductive females, whereas large male home ranges during the rut is likely related to seeking out mating opportunities; small winter ranges are likely due to movement constraints imposed by deep winter snows. During the winter season, we documented a high degree of site fidelity such that in 96% of cases (102/106) individual animals returned to the same home range it occupied during the previous winter. Within this context, we determined that males (29±5%) tended to use a larger proportion of their previous winter home range than females (12±3%). The high degree of site fidelity to relatively small winter home ranges highlights the importance of carefully managing such habitats for conservation.

Forage Response to Prescribed Fire in the Northern Rockies: Implications for Stone's Sheep and Elk

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ABSTRACT: Prescribed fire is used as a management tool to enhance ungulate habitats. Since the early 1980's, up to 7,800 ha have been intentionally burned annually for this purpose in northeastern British Columbia (BC). Yet, there have been relatively few long-term studies that have quantified the effects that fire has on plant and animal communities. Two focal grazers in northern BC, Stone's sheep (*Ovis dalli stonei*) and elk (*Cervus canadensis*), are known to benefit from fires, but the length of time that burned areas remain beneficial to these species is unknown. Previous work showed that when Stone's sheep used burned areas, it was most often younger-aged areas with higher nutritional quality, but initial increases in forage quality are believed to deteriorate over time. Elk exhibited less preference for ages of burns and may be more influenced by forage quantity. The goal of this project was to characterize the attenuation of the plant and animal (Stone's sheep and elk) responses after prescribed burns implemented in 2010 in the Besa-Prophet Area of northeastern BC. We resampled permanent transects on four burned areas and four unburned (control) sites during the year of the burn, 1 year after burning, and 7 years after burning. At each site, we monitored vegetative characteristics (forage quantity and quality) and animal use (fecal pellet counts) at different elevations (high, mid and low). We sampled in early May to capture winter forage availability and in July to index maximum summer forage availability. We also quantified the potential effects of grazing by comparing forage biomass in 8 range exclosures with paired plots outside the exclosures. In the short-term (one year after burning), both ungulate species increased their use of prescribed burned areas – likely in response to increased forage digestibility and rates of forage growth; and plant diversity returned to pre-burn levels. Our findings from this last year of the project help identify effective timing for the frequency of prescribed burning in northern BC. Our management recommendations focus on enhancing positive outcomes for Stone's sheep, while mitigating any negative effects from elk (potential competition and changes in predator-prey dynamics).

Use of Rapid Field-Based PCR Testing to Detect *Mycoplasma ovipneumoniae* Infection in Bighorn Sheep

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ABSTRACT: *Mycoplasma ovipneumoniae* (Movi) induced epizootic pneumonia has resulted in significant declines in bighorn sheep (*Ovis canadensis*, BHS) populations in the USA. Testing of BHS nasal swabs with real-time PCR (RT-PCR) for Movi infection has proven valuable in epidemiologic and ecologic studies of the disease, but does not produce results in time to support individual animal management actions without special arrangements for animal holding. The objective of this study was to evaluate rapid, animal-side testing using RT-PCR (Biomeme, Inc.) to detect Movi in sheep nasal swabs. Duplicate nasal swabs were collected from 53 BHS in Hells Canyon. Animals were considered positive if Movi was detected in either or both swabs. DNA was extracted from one swab using Biomeme reagents and analyzed in the field using the Biomeme RT-PCR instrument/two3 PCR machine (B-DNA/B-PCR) and the second swab was extracted

and tested by Conventional laboratory analysis (C-DNA/C-PCR). Movi was not detected using B-DNA/B-PCR in any of the tested BHS, while C-DNA/C-PCR detected Movi in 2 animals. C-PCR detected Movi using B-DNA from one of these two animals. Biomeme and conventional laboratory PCRs were also used to test duplicate nasal swabs from 33 domestic sheep (DS). B-DNA/B-PCR detected Movi in 58% (19/33), compared to 64% (21/33) for C-DNA/C-PCR. Movi was detected by B-DNA/B-PCR in two DS that were negative by C-DNA/C-PCR, while C-DNA/C-PCR detected Movi in four DS that were negative by B-DNA/B-PCR. C-PCR also detected Movi using B-DNA from these latter four animals. In all, 86 BHS and DS were tested by B-DNA/B-PCR and C-DNA/C-PCR; Movi was detected in 25 animals by one or both methods. Considering these 25 animals as 'true positives', the diagnostic sensitivity for Movi detection was 76% for B-DNA/B-PCR and 92% for C-DNA/C-PCR. Results indicated that swab-to-swab variation in sampling and the presence of inhibitory substances in DNA extracts contributed to the imperfect sensitivity of both tests. This study demonstrates the field applicability of Biomeme test and identified areas where improvement is needed.

Monitoring of Hunted Mountain Goat Populations in West-central Alberta: Insights Gained Over More Than Four Decades.

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ABSTRACT: Mountain goat (*Oreamnos americanus*) populations were monitored in west-central Alberta from 1971 to 2017. During the initial period (1971 – 1988) most populations were subjected to an either sex harvest regime of 5% of minimum helicopter counts. Following a series of years of declining numbers, the hunting season was closed in 1988 and remained so until 2000. During this period a kid mortality study was conducted, a provincial management plan was prepared and some, but not all, herds recovered. A hunting season was re-instituted in 2000 under a more conservative harvest regime of 1-2% of observed animals with efforts to focus harvest on males only. Over the last 10 years, both hunted and unhunted herds have again declined even under a very conservative hunting season. Concurrently, poor recruitment and decreased survival of adults has resulted in a strong decline of the unhunted Caw Ridge population. Potential causes for these declines are discussed.

Assessing Dall's Sheep Horn Morphometrics as a Management Tool

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ABSTRACT: Dall's sheep (*Ovis dalli*) are a coveted big game species pursued by a relatively small but passionate group of hunters across 8 mountain ranges in Alaska. The Alaska Board of Game determines state harvest regulations and has recently been inundated with public proposals aimed at altering sheep management. Proposals are directed at reducing a perceived level of competition between resident and non-resident hunters, and to address a possible lack of legal rams available for harvest. Specifically,

many hunters believe that all legal rams are harvested each year and want to increase their availability by reducing the hunting opportunities available to non-residents. Alaska hunting regulations are complex, but generally, most sheep hunting is managed under a full-curl harvest strategy. Full-curl is defined as: the tip of one horn has grown through a 360˚ circle described by the outer surface of the horn when viewed from the side, or both horn tips are broken, or the sheep is 8+ years old. Since 2004, successful hunters are required to seal sheep horns at Alaska Department of Fish and Game offices. In 2016, we began a study to evaluate horn morphometrics as a tool to inform management decisions. We measured and photographed ~60% of harvested rams in 2016 (474 of 783), and 2017 (483 of 798). For each horn, we quantified age, total horn length, total degree of curl, distance between consecutive annuli, and degree of curl by annulus segments. In 2016, the mean age at which rams achieved 360˚ curl was 8.5 years (range 5 to 12 years). In 2016, 19% of harvested rams were legally taken on criteria other than 360˚ of curl, while 28% of rams were harvested in the first year they became legal based on degree of curl. On the other hand, 53% of harvested rams were available for harvest during at least one previous hunting season after their horns grew through 360˚ curl. Our preliminary analyses indicate that hunters are only removing approximately half of all legal rams each year statewide. Using horn morphometric data to estimate ram escapement each hunting season will inform policy decisions.

Fatal Pneumonia in Bighorn Sheep Lambs: The Critical Role of *Mycoplasma ovipneumoniae* Carrier Ewes

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ABSTRACT: *Mycoplasma ovipneumoniae* is a candidate primary etiologic agent of pneumonia in bighorn sheep (*Ovis canadensis*). Introduction of *M. ovipneumoniae* into bighorn populations may result in severe all-age epizootics (5-100% mortality), followed by years of pneumonia-induced mortality in lambs (20-100% mortality). Recurrent lamb pneumonia in post-epizootic bighorn populations significantly reduces recruitment, impairing population growth and threatening population viability. It is hypothesized that ewes that are chronic nasal carriers of *M. ovipneumoniae* serve as the source of transmission of this pathogen to lambs. During the peri- and post- natal periods, initial dam-lamb infections are amplified by lamb-lamb transmission within lamb social contact networks, exposing all lambs in the group to the pathogen, even if only a small proportion of the dams are carriers. Captive bighorn sheep were used to test the hypothesis that the presence of *M. ovipneumoniae* carrier ewes within a nursery group precipitates lamb pneumonia outbreaks. Post-epizootic bighorn ewes (n=6) were commingled and longitudinally sampled for *M. ovipneumoniae* carriage over a 2-year period. One carrier and five non-carriers were identified. In 2017, these ewes were placed into two pens, with pen C1 (carrier 1) containing the carrier and one non-carrier ewe, and pen N (non-carrier) containing four non-carrier ewes. Both lambs born in pen C1 developed pneumonia, while the four lambs born in pen N remained non-pneumonic and survived. In 2018 we will repeat this experiment after moving the non-carrier ewe in pen C1 to pen N, and replacing her with two non-carrier ewes previously held in pen N. We have also added two additional pens (C2 and C3) containing one or more chronic carrier ewes. We predict all lambs born in the carrier pens will develop pneumonia, while all lambs born in pen N will again remain non-pneumonic. If this prediction holds true, both here and in parallel experiments at South Dakota State University, our hypothesis for the role of carrier ewes in precipitating pneumonia outbreaks in lambs will be strongly supported.

Projecting the effects of climate change on mountain goat population dynamics in Alaska

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ABSTRACT: Climate change represents a primary threat to species persistence and biodiversity at a global scale. Cold adapted alpine species, such as mountain goats (*Oreamnos americanus*), are especially sensitive to climate change and can offer key "early warning signs" about deleterious effects of predicted change. Among mountain ungulates, survival, a key determinant of demographic performance, may be influenced by future climate in complex, and possibly opposing ways. Demographic data collected from 447 mountain goats in 10 coastal Alaska, USA, populations over a 37 year time span indicated that survival is highest during low snowfall winters and cool summers. However, General Circulation Models (GCMs) predict future increase in summer temperature and decline in winter snowfall. To disentangle how these opposing climate-driven effects influence mountain goat populations, we developed an age-structured population model to project mountain goat population trajectories for 10 different GCM/emissions scenarios relevant for coastal Alaska. Projected increases in summer temperature had stronger negative effects on population trajectories than the positive demographic effects of reduced winter snowfall. In 5 of the 10 GCM/RCP scenarios, the net effect of projected climate change was extinction over a 70 year time window (2015–2085); smaller initial populations were more likely to go extinct faster than larger populations. Using a resource selection modeling approach, we determined that distributional shifts to higher elevation (i.e. "thermoneutral") summer range was unlikely to be a viable behavioral adaptation strategy; due to the conical shape of mountains, summer range was expected to decline by 17–86% for 7 of the 10 GCM/RCP scenarios. Projected declines of mountain goat populations are driven by climate-linked bottom-up mechanisms and may have wide ranging implications for alpine ecosystems. These analyses elucidate how projected climate change can negatively alter population dynamics of a sentinel alpine species and provide insight into how demographic modeling can be used to assess risk to species persistence.

Ecotypic Variation in Population Dynamics of Reintroduced Bighorn Sheep

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ABSTRACT: Selection of bighorn sheep (*Ovis canadensis*) for translocation historically has been motivated by preservation of subspecific purity rather than by adaptation of source stocks to similar environments. Our objective was to estimate cause-specific, annual, and age-specific mortality of introduced bighorn sheep that originated at low elevations in southern British Columbia, Canada (BC ecotype), or in the Missouri River Breaks region of central Montana, USA (MT ecotype). In North Dakota, USA, mortality was similar and typically low for adult female bighorn sheep from MT (0.09 ± 0.029 [SE]) and BC (0.08 ± 0.017) during 2000-2016. Median life expectancy was 11 years for females that reached adulthood (2 yrs old); however, mortality accelerated with age and reached 86% by age 16. Mortalities resulted primarily from low rates of predation, disease, accidents, and unknown natural causes (<0.04 [upper 90% confidence

limit]). Similar survival rates of female bighorn sheep from BC and MT, coupled with greater recruitment of bighorn sheep from MT, resulted in a greater projected rate of increase for the MT ecotype (λ = 1.21) than for the BC ecotype (1.02), and a more youthful age structure. These results support translocation of bighorn sheep from areas that are environmentally similar to areas that will be stocked. Potential benefits include more rapid population growth, greater resilience to and more rapid recovery from density-independent losses, an increased possibility that rapidly growing populations will expand into adjacent habitat, increased hunter opportunity, increased connectivity among herds, and a more complete restoration of ecosystem processes.

Poster Abstracts

- *Abstracts are organized alphabetically by author presenting (last name).*

Next Generation Ruggedness Indices for Modeling Escape Terrain of Desert Bighorn Sheep at Lone Mountain, Nevada

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ABSTRACT: Understanding habitat selection is critical to implementing management strategies that may benefit the population dynamics of mountain sheep. However, to ensure that resource selection functions are effective in identifying essential habitats to these mountain ungulates, the proper variables must be included in the modeling process. Delineating escape terrain has long been a primary focus of biologists trying to identify habitat that is used by females while they provision young. Several commonly used ruggedness metrics, such as vector ruggedness and arc-chord ratio, which attempt to quantify terrain ruggedness across the landscape, incorrectly identify features such as ridgetops and drainage bottoms as rugged. To alleviate these problems we have developed several new metrics. Two approaches, local vector ruggedness and standard deviation of curvature, only rely on a digital elevation model, whereas two other measures, proportion boulder/rock and the shadow index, used high-resolution aerial photography to develop a classification of these landscape features that indicate the presence of cliffs. We test the efficacy of each of these new methods at mapping rugged terrain against three commonly used ruggedness indices: vector ruggedness, arc-chord ratio, and planar to surface area ratio. Next, we compare both the old and new ruggedness indices, in combination with other variables, such as slope steepness, distance to ridgelines, and distance to drainages, to determine whether these new metrics more effectively delineate escape terrain for females with lambs. Our preliminary results suggest that these new ruggedness indices are effective at reducing confusion with ridgelines and drainages compared to the more traditional ruggedness indices, and may reduce the need for using additional variables, such as distance to ridgeline and distance to drainage bottoms to effectively delineate escape terrain. These ruggedness indices are widely applicable to any species that relies on escape terrain to avoid predators while provisioning young.

Investigating Disease Susceptibility in Desert Bighorn Sheep

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ABSTRACT: Gene-based diagnostics such as gene transcription provide an innovative, minimally-invasive tool that improves our understanding of the health of species of concern like desert bighorn sheep (*Ovis canadensis nelsoni*). By concurrent evaluation of transcript levels for genes representative of multiple internal systems such techniques can provide measure of a physiological response of individuals as well as populations to environmental stressors like pathogens, nutritional deficiency, or contaminants. We developed real-time PCR assays for 14 genes of interest and two reference genes. The subject genes react to stressors that can activate immunological and physiological responses that include inflammation, cell signaling, detoxification, antiviral, antibacterial, apoptosis, or general stress. Initial results from bighorn sheep in the River, Muddy, and Bare mountains and from the Pintwater Range, Nevada, indicated unique transcript profiles associated with each population. Stressor-specific analyses of gene transcription profiles can inform management actions that may mitigate stressor impacts and improve bighorn sheep recovery.

Mountain Goat Monitoring in Yoho, Kootenay, and Banff National Parks of Canada

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ABSTRACT: Protected areas, such as national parks, often contain large expanses of undisturbed wildlife habitat interspersed with human activities and infrastructure. Linear disturbances such as highways can fragment habitat while human land-use activities, recreation, and developments can displace wildlife from key resources. Determining the effects of anthropogenic influences on sensitive wildlife, such as mountain goats (*Oreamnos americanus*), is an important aspect of monitoring and managing protected landscapes for long-term sustainability. We outline key mountain goat monitoring tools used in Kootenay, Yoho, and Banff National Parks, which include remote wildlife cameras deployed at known mineral lick sites, aerial surveys, and the use of GPS tracking collars. Preliminary results are presented and discussed within the context of landscape planning and management.

Wild Sheep Ram Hunting Permit Process for Western States and Provinces

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ABSTRACT: A questionnaire was completed in early 2018 by 18 of the 20 wild sheep program managers in the western U.S states and Canadian provinces on their ram hunting permit/tag process and season structure and limited hunt results. A similar review of west-wide ram harvest strategies was conducted 10 years ago. The goal of the questionnaire was to: review the demographic information collected and guidelines and criteria used in setting ram hunting permit/tag numbers; compare season structure and harvest metrics; and challenge jurisdictions to use the best available science and consider more ram hunting opportunities without sacrificing ram horn quality. Most agencies' primary objective of their

aerial or ground surveys is animal composition to evaluate lamb ratios and ram age structure with 25% also wanting minimum count or detection of marked individuals for mark-resight estimate. Ten agencies classify rams based primarily on Geist's ram categories with Class IV rams as 8+ years of age, with others using a modified classification. Nine agencies use a model to estimate hunt unit population size, with 6 that correct for sightability bias on some herds, and only 1 that generates confidence intervals for their estimate. Alberta is exploring PopR Integrated modeling software. Most agencies use a guideline of the percent of the estimated population size, total rams, or mature rams to determine ram hunting permit numbers. One agency has no standard guideline. Agencies have a wide range of metrics and values for guiding ram permit numbers: 2.5 - 4% of total population - 3 (BC, CO. YK); 4.5% of all rams – 1 (CO); 7 – 10% of all rams – 6 (BC-bighorn, AZ, ND, NV, SD, NM); 10% of ¾ curl + rams – 2 (TX, MT); 15 – 25% of ¾ curl + rams – 7 (ND, CA, AB, MT, WA, AZ, NM); 20 - 30% of observed Class III & IV rams – 2 (ID, UT); 6 – 8 yr-old avg. age ram harvest previous year – WY; and 7% of previous year ram harvest 40"+ horn length – AK. The range of average ram harvest age by subspecies were: 7.8 – 9.3 for Dall/Stone; 6.5 – 7.0 for California; 6.4 – 10 for Rocky Mountain; and 6.4 – 9.0 for Deserts. Most jurisdictions have a similar hierarchical decision/approval process of: field/regional review of wild sheep data and information and suggest/ submit recommendations; program lead and Bureau/Division heads provide oversight and support; wide array of stakeholder involvement; and final Board/Commission review and approval. Many agencies follow guidance provided by their wild sheep management plan. One state has a single committee that sets permit numbers with no public process. One jurisdiction is moving to a formal "Structured Decision Making" (SDM) process to better engage stakeholders, provide transparency, account for uncertainty and values/opinions, while incorporating science and following management objectives.

Determining Population Management Unit Boundaries for Mountain Goats in Skeena Region

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ABSTRACT: Recent inventory work has occurred on three mountain complexes northeast of Smithers (Blunt Mountain, Netalzul Mountain and Goat Mountain), which has suggested a potential decline on Blunt Mountain, a potential increase on Netalzul Mountain, and relatively stable numbers on Goat Mountain. Determining if goats on these mountain complexes are one, two or three population management units (PMU), will help ensure robust and biologically based management of mountain goats. Mountain goat PMU's have currently been derived for the Skeena region based on expert opinion along with using major watershed boundaries that may or may not serve as a barrier to animal movement throughout the majority of the Region. In Skeena south, PMU's have been left as LEH boundaries for the time being, until such time that better biological information exits. Having biologically meaningful PMU's will improve the management of goats, ensuring values such as conservation and appropriate harvest opportunities are evaluated and maintained at an appropriate scale. In this study we will use GPS collar locations and genetic data from both male and female mountain goats, on three adjacent mountain complexes, to define population structure and refine PMU's. The information will provide quality assurance that can be applied to future genetic work and further refine PMUs for the remainder of Skeena Region. The project will also assess habitat selection of collared goats and assess the currently designated ungulate winter ranges. It will also be the first collection of comprehensive baseline animal health for mountain goats in BC through live and mortality sampling.

Challenges of Predation Monitoring and Management for Sierra Nevada Bighorn Sheep

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ABSTRACT: Predation by mountain lions (*Puma concolor*) on federally endangered Sierra Nevada bighorn sheep (*Ovis canadensis sierrae*) has been considered an important management concern since their listing under the Endangered Species Act in 1999. However, quantifying the likelihood and impact of predation is challenging, despite predation being the leading known cause of mortality. We evaluated cause-specific survival rates from radio-marked animals but in some cases these estimates were hampered by small sample sizes, where the fate of a small number of animals can disproportionately influence calculations. An alternative is to incorporate all known deaths from predation, including uncollared animals (which comprised 13% of all known mortalities, 1999-2017), and calculate the proportion of the population killed. Unfortunately, this method is hampered by imprecise count data in some herd-years, despite many counts being near censuses. A further challenge involves monitoring lions themselves because (1) most appear not to prey on bighorn sheep (only 16 of 81 lions monitored during 1999-2017 were known to kill bighorn sheep) and (2) when predation does occur, it is episodic. Of the 4 herds that experienced the most predation in the last 19 years, "predation episodes" occurred in only 7 of 76 (9.2%) herd-years. While this lack of consistent predation may be partially attributable to predation management activities from 1999-2011, an absence of predation in herd-years from 2012-2016, when no predation management activities occurred but lions were documented to be present, indicates that this lion population has intrinsic annual variability in its impact on bighorn sheep. Thus, as predation monitoring and management is resumed, substantial effort may be expended monitoring lions that are unlikely to prey on bighorn sheep. However, inattention to predation could jeopardize achievement of recovery goals in a timely manner. For example, during the winter of 2016-17 we unexpectedly documented a significant predation episode in a herd where predation was previously thought to be unimportant. This recent episode highlighted that despite challenges and uncertainties, under certain conditions, predation of Sierra Nevada bighorn sheep by lions can clearly impede recovery efforts and continued monitoring and management is warranted.

Developing a Spatial Tool to Enable Monitoring of Aircraft Flights and Compliance with Avoidance Strategies for Helicopter Skiing Operations in the Skeena Region

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ABSTRACT: Guidelines to mitigate the potential disturbance and displacement effects of helicopter-skiing in areas occupied by mountain goats (*Oreamnos americanus*) through vertical and horizontal setback distances have been in place in British Columbia since the early 2000's. In the Skeena region, detailed mitigation strategies have been developed to ensure helicopter flight paths avoid areas occupied by mountain goats during the critical winter period. Without the ability to remotely track flight paths,

assessing compliance with avoidance measures is logistically challenging in the remote mountainous terrain used by both mountain goats and the heli-skiing sector. A simple spatial tool has been created to provide immediate feed-back to operators and enable performance review of individual heli-skiing operations and flight paths relative to mountain goat habitats. The tool is based on a combination of Google Earth, vertically extruded mountain goat winter range habitat polygons and Garmin Global Positioning System flight tracking. The tool enables a 3-D visual analysis of flight path performance relative to avoidance zones. An ArcGIS Visibility function also provides a more detailed assessment related to horizontal setbacks from key mountain goat winter range habitats. Continued "social license" for the heli-skiing sector to operate on public lands and within First Nation territories hinges on maintaining public confidence that commercial back-country recreation activities do not jeopardize the sustainability of wildlife populations. This tool provides an opportunity to effectively monitor and assess operator performance and enhance public confidence that appropriate protection measures are in place and being adhered to. Formal monitoring of adherence to provincial guidelines and site-specific mitigation strategies has been enabled through application of this tool, and the results for the 2016/17 ski season for some of the six heli-skiing operations in the Skeena Region are presented.

The Genetic Legacy of 50 Years of Desert Bighorn Sheep Translocations in Nevada

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ABSTRACT: Desert bighorn sheep (*Ovis canadensis nelsoni*) are an iconic western North American species that have been heavily managed throughout their range. Once thought to be the most abundant large mammal in the state of Nevada, dramatic declines in the mid 1900's reduced population sizes and restricted the range of desert bighorn sheep primarily to southern Nevada, though a few remnant populations persisted in central Nevada. To restore central Nevadan populations, the Nevada Department of Wildlife conducted several translocations of individuals from multiple southern Nevada source populations, leading to the admixture of individuals with different genetic ancestry. Here, we used a genotyping-by-sequencing approach to generate genetic information at several thousand loci for hundreds of desert bighorn sheep individuals across the state of Nevada. We found evidence for strong population genetic structure between the source populations in southern Nevada, suggesting that substantial genetic variation still exists in the state. However, almost all central Nevadan populations have genetic signatures that strongly resemble those from their translocation source populations. Finally, one central Nevadan population was genetically distinct from all other populations, and is likely the last bastion of central Nevadan genetic ancestry remaining in the state.

Observations and Recommendations During Capture of Bighorn Sheep

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ABSTRACT: Bighorn sheep are captured routinely for monitoring and research yet questions remain regarding numerous aspects of handling procedures and the effects of handling on individuals and populations. We evaluated a variety of factors that have the potential to affect the demography and behavior of bighorn following captures. We captured 653 Sierra Nevada bighorn sheep using helicopter net-gun during 2001 – 2017. Animals were restrained using hobbles and blindfolds. Captures occurred at elevations between 5,000 and 14,000 feet and most were ferried to a central location for handling. Handling times varied between 10 minutes and 2 hours. Body temperatures ranged from 99.0 to 107.7° F. Our rate of capture mortality was 2.7%. We examined the relationship among survival, vital rates (temperature, respiration and heart rate), and handling time. Movement rates and home range sizes of animals with previously deployed GPS collars were compared pre- and post-capture. We recommend continuing to hold animals with elevated temperatures to ensure adequate cooling rather than releasing hot animals. We also provide detailed recommendations for collar fitting.

When, Where, and Why Do Contacts Occur? Investigating Interactions Between Bighorn Sheep in and Around Glacier National Park

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ABSTRACT: Understanding mechanisms of social interactions can help address questions in evolutionary, behavioral, and infectious disease ecology. Trade-offs between costs and benefits of sociality can operate at multiple scales, and factors influencing sociality at one level are likely different from those at another level. We investigated contacts of 87 male and female bighorn sheep (*Ovis canadensis*) in and around Glacier National Park in Montana, USA from 2002-2011 using GPS locations. We examined relationships between contact locations, movement, and extrinsic variables (e.g., land cover, NDVI, distance to escape terrain) using a resource selection function. To assess types of contacts, we separated contacts by dyad type (male-male, female-female, and male-female) and examined the strengths of association for dyads with intrinsic variables (e.g., relatedness, space-use overlap, dyad type, and homophily) using a generalized linear mixed model. Finally, we identified subpopulations through contact networks using different distance criteria (25 - 100m). Most contacts occurred in March for same sex dyads and from November to January for male-female dyads. Although more contacts occurred in high quality habitat, contacts were more likely in lower quality habitat for same sex dyads. For male-female dyads, however, contacts occurred more and were more likely in high quality habitat. Female-female dyads with high space-use overlap during the summer, moderate relatedness, and of the same age class had highest rates of association. Different contact criteria identified 3 to 4 subpopulations. Together, these results give us the power to predict where contacts are most likely to occur, which can inform disease management.

Northern Wild Sheep and Goat Council

NWSGC Symposia History 1970-2018

Date	Symposium	Location	Symposium Coordinator/Chair	Proceedings Editor(s)	NWSGC Executive Director
May 26-28, 1970	NWSC 1	Williams Lake, BC	Harold Mitchell		
April 14-15, 1971	NAWSC 1	Fort Collins, CO	Eugene Decker/ Wayne Sandfort	Eugene Decker	
April 11-13, 1972	NWSC 2	Hinton, AB	E.G. Scheffler		
April 23-25, 1974	NWSC 3	Great Falls, MT	Kerry Constan/ James Mitchell		
Feb. 10-12, 1976	NWSC 4	Jackson, WY	E. Tom Thorne		
April 2-4, 1978	NWSGC 1	Penticton, BC	Daryll Hebert/ M. Nation	Daryll Hebert/ M. Nation	
April 23-25, 1980	NWSGC 2	Salmon, ID	Bill Hickey		
March 17-19, 1982	NWSGC 3	Fort Collins, CO	Gene Schoonveld	James Bailey/ Gene Schooneveld	
April 30-May 3, 1984	NWSGC 4	Whitehorse, YK	Manfred Hoefs	Manfred Hoefs	Wayne Heimer
April 14-17, 1986	NWSGC 5	Missoula, MT	Jerry Brown	Gayle Joslin	Wayne Heimer
April 11-15, 1988	NWSGC 6	Banff, AB	Bill Wishart	Bill Samuel	Wayne Heimer
May 14-18, 1990	NWSGC 7	Clarkston, WA	Lloyd Oldenburg	James Bailey	Wayne Heimer
April 27-May 1, 1992	NWSGC 8	Cody, WY	Kevin Hurley	John Emmerich/ Bill Hepworth	Wayne Heimer
May 2-6, 1994	NWSGC 9	Cranbrook, BC	Anna Fontana	Margo Pybus/ Bill Wishart	Kevin Hurley
April 30-May 3, 1996	NWSGC 10	Silverthorne, CO	Dale Reed	Kevin Hurley/ Dale Reed/ Nancy Wild (compilers)	Kevin Hurley
April 16-20, 1998	NWSGC 11	Whitefish, MT	John McCarthy	John McCarthy/ Richard Harris/ Fay Moore (compilers)	Kevin Hurley
May 31-June 4, 2000	NWSGC 12	Whitehorse, YK	Jean Carey	Jean Carey	Kevin Hurley
April 23-27, 2002	NWSGC 13	Rapid City, SD	Ted Benzon	Gary Brundige	Kevin Hurley
May 15-22, 2004	NWSGC 14	Coastal Alaska	Wayne Heimer	Wayne Heimer/ Dale Toweill/ Kevin Hurley	Kevin Hurley
April 2-6, 2006	NWSGC 15	Kananaskis, AB	Jon Jorgenson	Margo Pybus/ Bill Wishar	Kevin Hurley
April 27-May 1, 2008	NWSGC 16	Midway, UT	Anis Aoude	Tom Smith	Kevin Hurley
June 7-11, 2010	NWSGC 17	Hood River, OR	Craig Foster	Vern Bleich	Kevin Hurley
March 12-15, 2012	NWSGC 18	Kamloops, BC	Steve Gordon/ Steve Wilson Mari Wood	Steve Wilson/ Mari Wood	Kevin Hurley
June 2-5, 2014	NWSGC 19	Fort Collins, CO	Janet George	Bruce Watkins, Ricki Watkins	Kevin Hurley
May 9-12, 2016	NWSGC 20	Moscow, ID Pullman, WA	Hollie Miyasaki,/ Rich Harris/ David Smith	Rich Harris	Kevin Hurley
May 21-24, 2018	NWSGC 21	Whitefish, MT	Brent Lonner/ Bruce Sterling	Justin Gude	Kevin Hurley

NOTES

Northern Wild Sheep and Goat Council